Protocols for Snow Pit Work
NASA GODDARD
HISTORY OF WINTER (HOW)

A snow pit is a trench exposing a snow face that reveals for study the entire thickness of snow on the ground at the location of interest.
Snow pits are routinely examined in order to evaluate avalanche danger. They are also important study sites for researchers interested in the hydrologic consequences of the snow contained in the snow pack. In some regions of the west the snow pack provides almost all of the water that will be available for the yearly demands. Consequently NASA researchers using remote sensing satellites are interested in the remote evaluation of the water content of the snowpack.

The snow pit will be studied to understand the stratigraphy of the snowpack and to correlate the layering with weather events leading to a better understanding of the history of winter. Broadly considered the snow pit studies can address snow cover classification related to global climate generally.

Teacher Background Information: This information for teachers is taken from the OLCG Snow Inquiry unit and relates to performance standards as indicated
http://www.uaf.edu/olcg/teaching/Snow/snow.inquiry.html
Performance Standards:
Alaska Science Content Standard A2: Understand physical changes and interactions in matter result in observable changes in the properties of matter
Alaska Science Content Standard B1: Processes of science (observe, predict, infer, classify, collect and analyze data)
Alaska Math Content Standard: Measurement
Alaska Math Content Standard: Statistics and Probability
Target Concept:
The physical properties of snow can change due to heating, cooling, and physical forces such as pressure and friction.

Snowflakes begin as delicate crystals but are soon transformed into the granular crystals and lumps of ice that are found within and at the bottom of layers of snow. The process by which snow crystals change in composition or structure is known as snow metamorphism. Pressure and temperature are the two most influential agents of change.

Pressure: Snow crystals change due to the physical compaction of snow under its own weight as well as under the weight of human or animal traffic on top of the snow. During such pressure metamorphism, snow crystals get pressed together and interlock more closely resulting in decreased snow pack thickness and increased snow pack density and strength.

Temperature: Obviously, melting and re-freezing cause changes in snow crystals, but snow changes even when temperatures are relatively constant. Constant molecular activity causes evaporation of the many fine points that form angles between the delicate crystals. This evaporation makes the air around the crystals very moist. The moisture re-condenses (because of the coldness) and deposits particles of ice onto the flatter, smoother surfaces of the crystals. It is this continuous evaporation from sharper points and condensation onto flat places which transforms the crystals into little lumps of ice.

Temperature Gradient: Often there is a difference in temperature between the snow at the bottom and top layers of the snow pack. In winter, when air is very cold, the snow at the surface of the snow pack is colder than the snow near the ground. This is because snow is a very good insulator, insulating the ground from the colder air temperatures. When the ground is warmer than the snow above it, water vapor is produced. This vapor can then rise and re-condense, creating characteristic, large cup-shaped crystals known as depth hoar. In the spring, the temperature gradient may be reversed, with temperatures warmest at the top of the snow pack and colder at the bottom. Warmer conditions may also cause the temperatures to be consistent throughout the snow pack.

Snow Layers: As snow accumulates and changes over time, it develops layers of snow marked by their physical differences and reflecting the life history of the snow pack. These layers are often broadly classified as new snow, firn, and depth hoar (but careful observers often distinguish other layers within these categories). In general the new snow layer consists of new sharp crystals lying loosely on the top of the snow bank and slowly being compacted by additional falling snow. Just below the new snow is a layer called firn. The firn consists of crystals that have lost their sharp edges due to evaporation, freezing and compaction. They are now rounded into more sphere-like shapes, in time becoming particles of ice. This snow is dense and the grains are more closely bonded together, which increases the mechanical strength of the firn layer. At the bottom of the snow bank is the depth hoar layer consisting of snow crystals that have metamorphosed into lumps of ice through evaporation, condensation, and compaction. This layer is more weakly bonded than either the firn or new snow layers. The depth hoar layer is loose and grainy. The crystals sift through your fingers and it is often nicknamed sugar snow.

Snow Density: Through most of the winter, snow density will usually increase deeper into the snow pack, until reaching layers where depth hoar has formed. Since the depth hoar layer is loose and grainy, these layers have lower densities. When warmer temperatures occur, the strength and density of the entire snow pack increases due to compaction.

Effects on Animals: Small mammals such as mice, voles and lemmings depend upon the insulating value of snow. Although at least 3 feet of snow assures adequate warmth, as little as 6 inches provides some advantage. Small mammals can easily tunnel through loosely packed depth hoar crystals formed at the base of the snow pack and thereby take advantage of warm temperatures in the snow / ground interface. This subnivian environment reduces the effect of wind, extreme temperature variations and predation. Food such as roots, stems, buds, and carrion are abundant.

The snow pit work relates to science content standards as indicated above and appropriately addresses science content strands.

Components from each of the five science content strands:

http://www.ed.mtu.edu/esmis/winter/standards.html
These content matches are from the Michigan curriculum standards and were developed by Dr. Mary Hindelang.

Constructing New Scientific Knowledge - how we investigate and learn about our world in winter
Reflecting on Scientific Knowledge - what constitutes knowledge about winter and scientific theories of adaptation
Using Scientific Knowledge in Life Science - winter and its relationship to cells, organization of living things, heredity, evolution, and ecosystems
Using Scientific Knowledge in Physical Science - the effects of cold on matter and energy, changes in matter, waves and vibration
Using Scientific Knowledge in Earth Science - the geosphere, the hydrosphere, atmosphere and weather, and the solar system in winter
Data Analysis and Statistics - organize, interpret, and transform data into useful knowledge to make predictions and decisions based on data
Number Sense and Numeration - quantify and measure objects, and represent and communicate ideas in the language of mathematics
Inquiry and Research - define and investigate important issues and problems using a variety of resources, including technology, to explore and create texts

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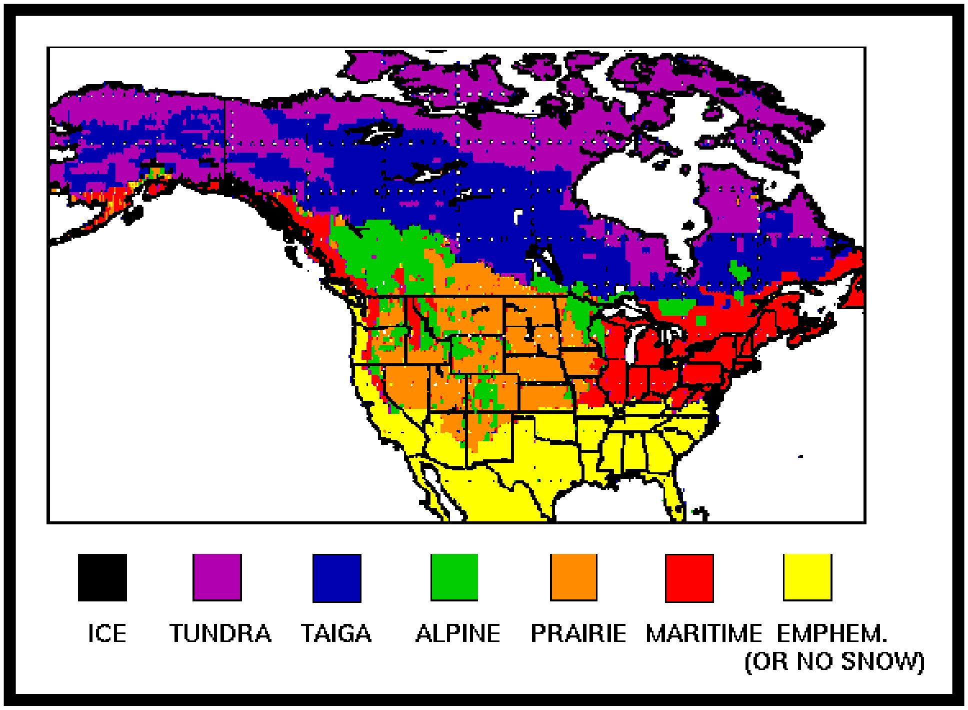
To follow are two diagrams taken from work by Sturm, Holmgren and Liston (1995). The top diagram is one that illustrates a Snow Cover Classification. You will note the similarity in language to Biomes. Consequently there is a climate connection. The bottom diagram is what you might expect in idealized terms for a snowpit from each of the regions. The importance of the science connection then is to help enhance the classification, which is a generalization by Sturm and fellow researchers.



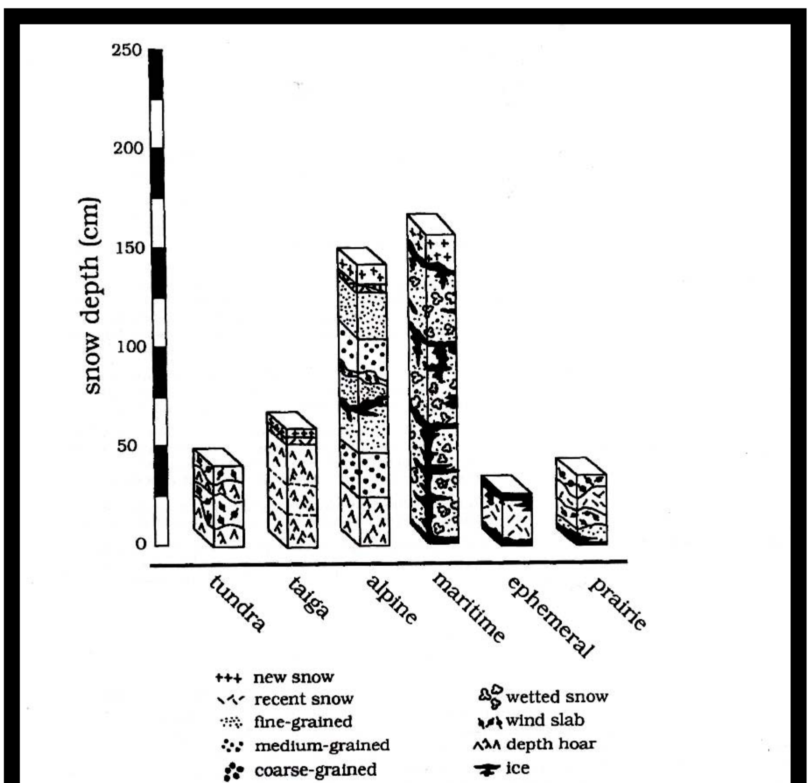
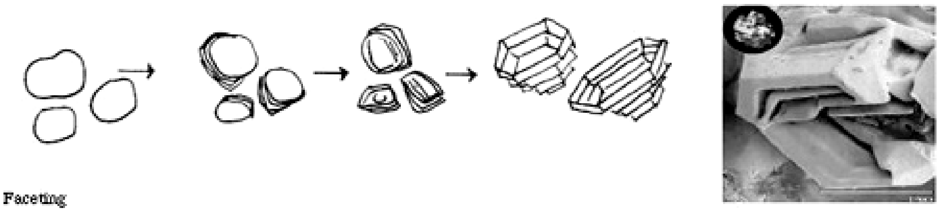


FIG. 2. The basic stratigraphic and textural attributes of each class of snow cover as they would appear in middle to late winter. Symbols follow Colbeck et al. 1992.



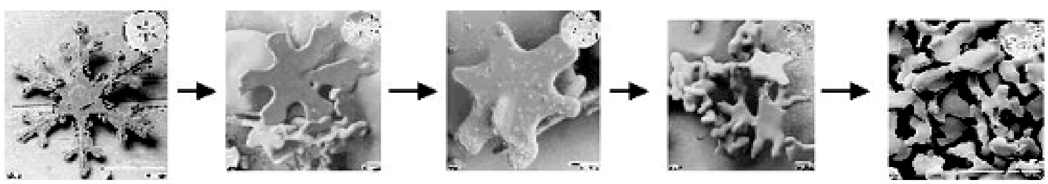
Faceting

The faceting process builds angular grains (facets) which bond relatively poorly to one another and other grains creating a snowpack (or layer) that is generally increasingly weak.

When the temperature gradient is strong (> 1 degree / 10cm) water vapour moves rapidly from warm grain surfaces to colder surfaces. Because the snowpack usually is warm (at or near 0 degrees C) at the ground and colder at the surface, ice sublimates from lower, warmer grains and is deposited onto colder grains higher up in the snowpack. These colder grains first develop sharp corners, then stepped facets.

If the faceting process continues, large, six - sided hollow or filled cup shaped grains called depth hoar are formed. Depth Hoar is common in Rocky Mountain climates, around large rocks and high shrubs, and where the snowpack is thin. The following conditions promote faceting :

A strong temperature gradient, generally greater than 1 degree / 10cm (which quickly drives water vapour from warm areas to cold)
Loose, low density snow (which facilitates the free movement of water vapour between grains)
Presence of crusts (which concentrate water vapour, promoting vapour transfer in the concentrated area)
Moderate snow temperature (which maximizes the amount of vapour the snowpack can hold but does not reduce the overall temperature gradient significantly)



The rounding process builds rounded grains (rounds) which bond well to one another creating a snowpack (or layer) that is generally increasingly strong.

In weak temperature gradients(<1 degree / 10cm) sublimation typically moves ice from convex surfaces (points) to concave surfaces (hollow in 2 stages:

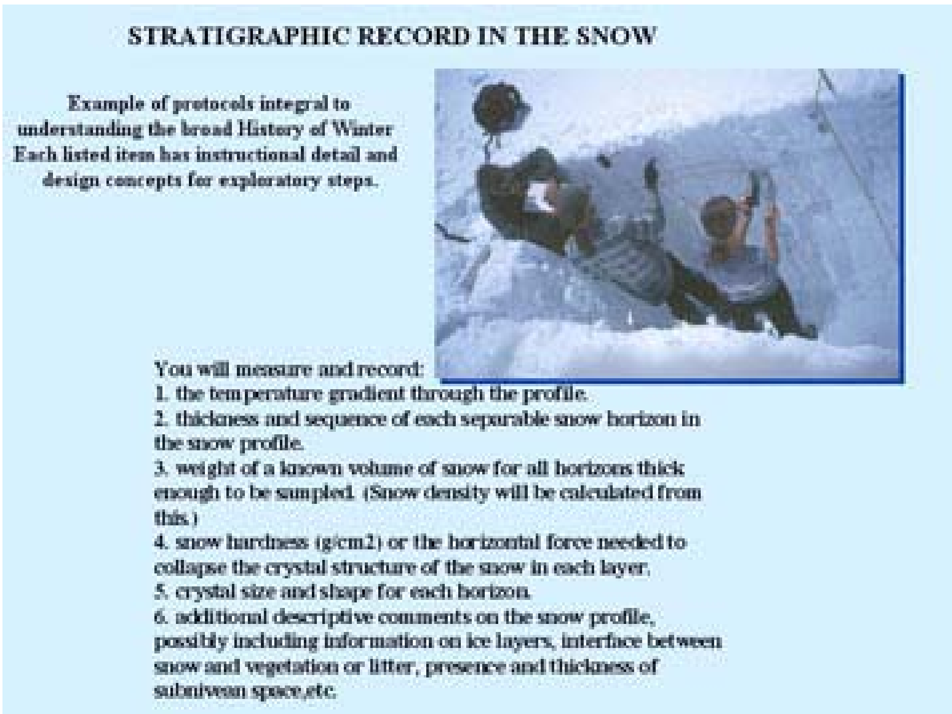
1. In the initial stage of rounding, the sharp ends of new crystals and the points of faceted grains sublimate and the resulting water vapour is deposited in concave areas. At high temperatures, molecules also glide along the grain surface from convexities to concavities. As well, large grains with broad curvatures grow at the expense of small grains with sharp curvatures. The result is a concentration of mass with a minimum surface area.
2. Under weak temperature gradients, water vapour moves from warm areas to cold, but the rate of movement is much slower than in strong temperature gradient environments. Slow moving vapour is deposited on the colder surfaces in a more homogenous manner and the faceted, stepped pattern associated with a strong temperature gradient does not occur.

The following conditions promote rounding:

- A weak temperature gradient generally less than 1 degree C per 10 cm (which moves water vapour slowly from warm areas to cold)
- Dense, tightly packed snow
- Small grains (which produce denser snow)
- A high snow temperature, typically above -10 degrees C (which promotes weaker temperature gradients)

Preparing the Snow Pit

Objective of this "lesson": To create a vertical snow surface face that will enable the study of the snow pack. The purpose is to use the snow pit face to identify the characteristics that will describe the snow stratigraphy.



http://www.comet.ucar.edu/class/hydromet/09_Oct13_1999/docs/cline/comet_snowhydro/

Brief Description: Choose site representative of the area. The site should be unaltered by man or machines. Digging a trench in the snow pack will expose the vertical face all the way to the ground surface and enable the researcher access to this vertical face. In a classroom setting several sites may be chosen some of which include drifting etc. These can then be contrasted.
Before you begin pay attention to the sun. You want to take most of the measurements when the sun is not on the snow face that you will create.

List any safety concerns/cautions: appropriate cold weather clothing should be worn.

Materials needed: flat blade shovel and meter stick or measuring rule that will be used to measure the extent of the vertical snow face. Golf tees or sticks can be used as anchor points for the measuring device. This scale would remain in place for all measurements.

Procedures/protocol:
1. Choose a site representative of the area snowfall. Make sure that you pay attention to the orientation of the prospective pit, as you would want to make the observations with the pit face in the shade.
2. Determine and record the site information indicated on the data table.
3. Dig vertically through snow pack exposing a smooth face approximately 1-2 meters wide so that several people could make observations comfortably.
4. Extend smooth face down to ground surface.
5. Expand the pit to accommodate easy visual access of snow face for several researchers working at the same time.
6. Take care not to alter the exposed test surface.
7. Anchor the measuring tape or meter stick and then record the total thickness of the vertical face of the snow pit that will be your research surface.

Data Table: See Georeference data table
This table should contain all descriptive information identifying the location and the characteristics of your snow pit.

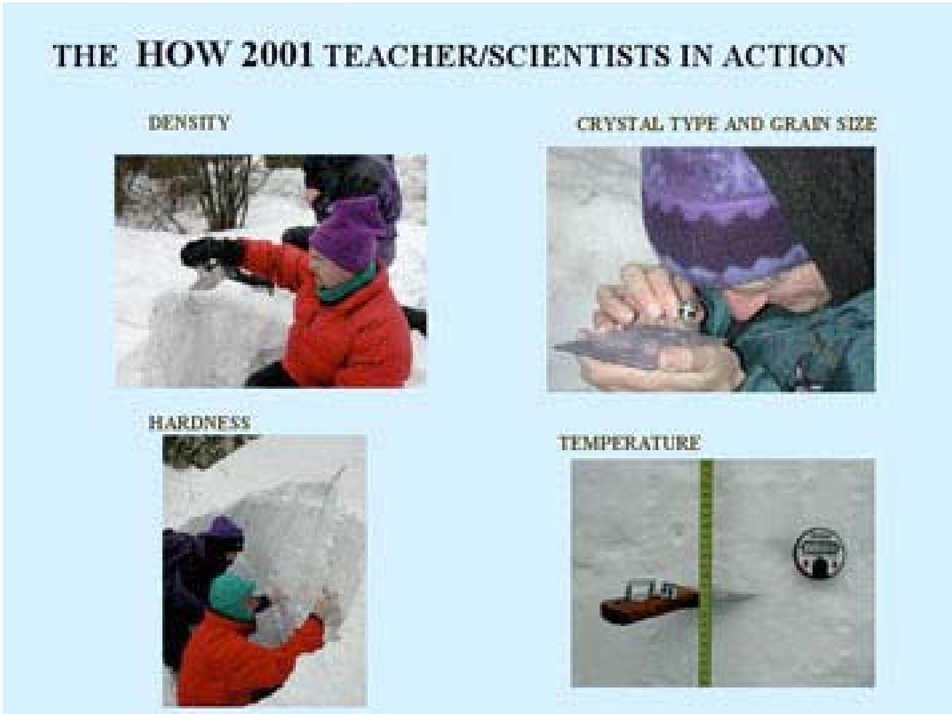
Snow Pit Investigation Georeference Data Table:

Date:	
Time:	
Site description:	
Latitude:	
Longtitude:	
Elevation:	
Air temperature:	
Slope Aspect: (N, E, S, W)	
Percent Slope: (Use clinometer)	
MUC:	
Depth of Accumulation:	
Surface under pit:	
Cloud cover:	

Sample Data Table (Lake Placid):

Date:	2/14/01
Time:	1:14 PM EST 7:14 UTC
Site description:	Near Mirror Lake (Eastern side) Northwood School Adirondack Park, NY
Latitude:	44° 17’ 42N
Longtitude:	73 °58’ 29W
Elevation:	566 m
Air temperature:	7° C
Slope Aspect: (N, E, S, W)	North
Percent Slope: (Use clinometer)	5%
MUC:	1222 Woodland, Cold Deciduous with evergreens
Depth of Accumulation:	41 cm
Surface under pit:	Grass
Cloud cover:	Overcast

Conclusion(s): Is the site suitable and representative? Have you completed all identification procedures?



This image shows the HOW teachers in the process of taking the measurements that are described below

Naked Finger Test

Purpose of this "lesson": initial qualitative determination of the stratigraphic layers in the snow pack. This test will give you an indication of what you will encounter in your research intended to describe the vertical face of the snow pit.

Brief Description: Use tip of index finger to probe a vertical column of snow from surface to ground level.

List any safety concerns/cautions: appropriate cold weather clothing, slope of site.

Materials needed: index finger, marking material such as golf tees or popsicle sticks, and materials to record data, metric tape measure (centimeters & meters marked).

Procedures/protocol:
1. You should have placed the metric tape or the meter stick with zero (0) at the ground. (Remember zero is at ground surface, increasing value with increase in height).
2. Start at top of snow surface
3. Use bare index finger to gently poke snow face all the way to the ground level. This will be the test case to acquaint you with the procedure.

4. Move the real test line to the right of your just completed test and proceed in the same way from top to ground this time recording information and using golf tees or sticks to mark the important ice layers or horizons. Record description of hardness, density, and crystal structure, and locate on your record sheet the location of each of your markers.

Data Table: (see following data table for recording the depth and observation of information at the location of each of the markers).

Snow Pit Investigation Data Table: Indicate at what depth a difference is observed. (Expand table as needed).

Naked Finger Test

Depth (cm)	Observation

Sample Data Table (Lake Placid):

Naked Finger Test

Depth (cm)	Observation
33 cm	Ice
21 cm	Ice
2 cm	Ice

Conclusion(s): Initial identification of stratigraphy from bottom to top (even though the measurements were taken from top to bottom) - soft & hard layers, potential sliding surfaces, cursory: density and water content, weaknesses, strengths and bonding.

Resources for additional information:

Knife Test

Research Area: Ice/Snow/Winter Ecology: Snow

Purpose of this "lesson": Secondary qualitative analysis of stratigraphy of the snow pack.

Brief Description: Use knife to slice vertically down through the snow pack.

Background Information/List any safety concerns/cautions: Caution when using sharp objects, appropriate cold weather clothing, slope of site.

Materials needed: Knife, marking material such as golf tees or Popsicle sticks, and materials to record data, metric tape measure (centimeters & meters marked).

Procedures/protocol:
1. You should have in place the metric tape or meter stick with: zero (0) at ground. Anchor body of tape measure on top of snow (zero at ground, increasing value with increase in height).
2. Start at top of snow surface as you had done with the finger test.
3. Use knife to gently slice down through snow face as with the finger test. This test is essentially a repeat of the finger test to help refine the profile information.
4. Note and record any change in hardness, density, and crystal structure.
5. Indicate significant changes in texture with marker placed in snow face.
6. Continue procedure down to ground surface and record all information as was done in the finger test.

Data Table: (see following data table for recording the depth and observation of information at the location of each of the markers).

Snow Pit Investigation Data Table: Indicate at what depth a difference is observed. (Expand table as needed).

Knife Test

Depth (cm)	Observation

Sample data table (Lake Placid):

Knife Test

Depth (cm)	Observation
33 cm	Ice layer
32- 22cm	Soft snow
21 cm	Ice layer
20-3 cm	Close packed snow
2 cm	Ice layer

Conclusion(s): Initial identification of stratigraphy from bottom to top - soft & hard layers, potential sliding surfaces, cursory: density and water content, weaknesses, strengths and bonding.

Temperature Gradient

Research Area: Ice/Snow/Winter Ecology: Snow

Purpose of this "lesson": To determine the vertical temperature gradient of the snow pack at the given site.

Brief Description: Using calibrated thermometers measure the temperature at 5-10 cm intervals from top to bottom in the snow pack. The measurement interval will depend on the thickness of the snow pack.

Background Information/List any safety concerns/cautions: appropriate cold weather clothing, slope of site.

Materials needed: thermometers (The thermometer should be initially calibrated by placing in an ice slush bath to determine the location of zero centigrade).

Procedures/protocol:

1. You should have the metric tape or meter stick in place with: zero (0) at ground level. Anchor body of tape measure on top of snow (zero at ground, increasing value with increase in height).
2. Measure the air temperature and record.

3. Measure the ground temperature and then the temperature immediately above the ground in the snow.
4. Measure the temperature every 5 or 10 cm in the snow pack. Record all the temperatures and then graphically present these.

Data Table: (see the following data table)

Includes 2-D graph: Y-axis = snow depth (cm), X-axis = °C, starting with zero (0) at lower right corner, and decreasing (negative numbers, temp below freezing point) to left.

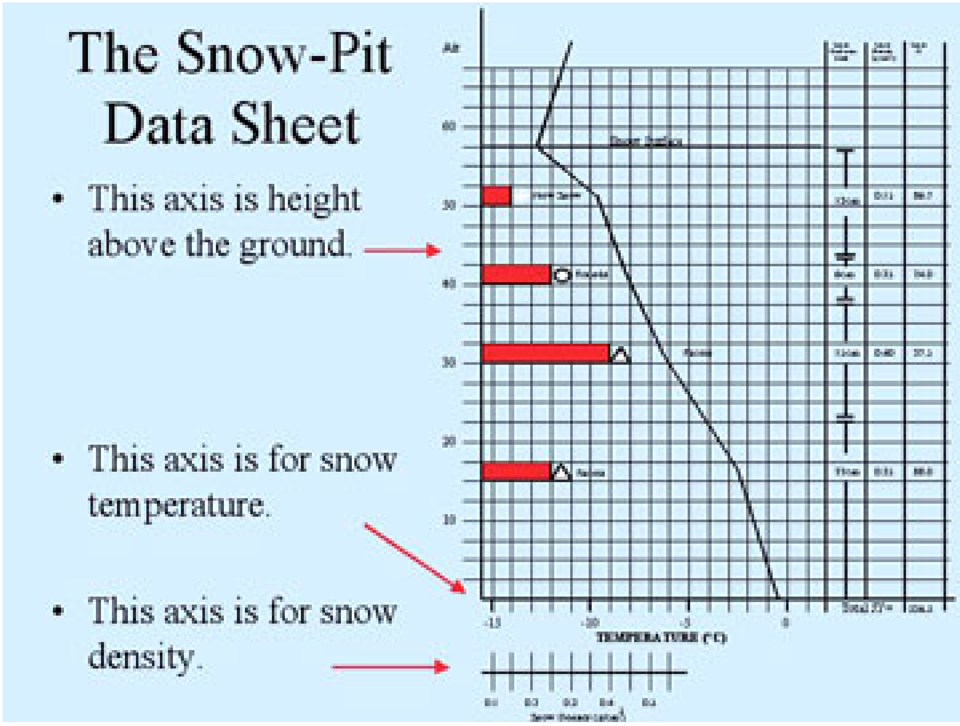
Snow Pit Investigation Temperature Gradient Data Table: (Expand as needed).

Depth of Accumulation (cm)	Temperature ° C

Sample data table (Lake Placid):

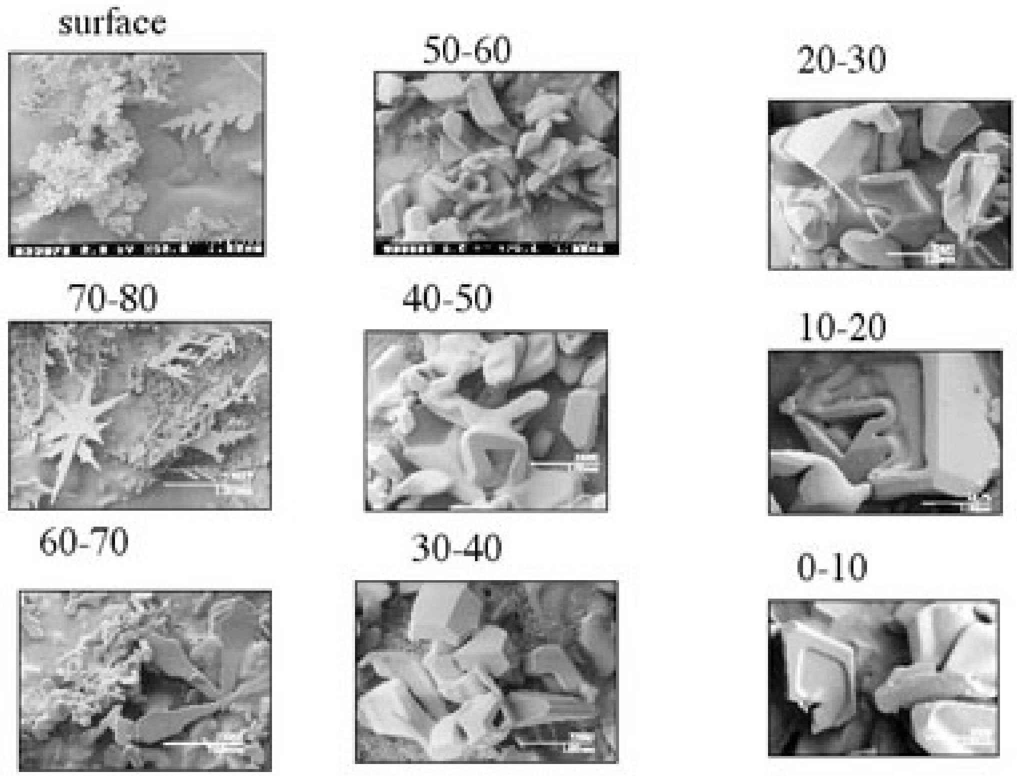
Depth of Accumulation (cm)	Temperature ° C
95	-0.3
90	-2.3
85	-3.3
80	-3.5
75	-3.5
70	-3.0
65	-2.7
60	-2.2
55	-1.7
50	-1.3
45	-1.1
40	-0.8
35	-0.2
30	-0.8
25	-0.5
20	-1.0
15	-3.0
10	0
5	-1.0

Conclusion(s): Initial identification of stratigraphy from bottom to top - soft & hard layers, potential sliding surfaces, cursory: density and water content, weaknesses, strengths and bonding.



Snow Crystal Classification

http://www.anri.barc.usda.gov/emusnow/comparison/comp2.htm



Examples of the type of grain shape variations that can be identified in the snow pack. These images are SEM images at liquid Nitrogen temperature. (USDA- Eric Erbe) The optical observations will be more difficult. The main idea is to identify the stratigraphic changes in snow grain crystal shape as best you can.

Purpose of this "lesson": To identify and classify snow crystals (grains) by type and size.

Brief Description: Sample each distinctive layer of snow column and use crystal card (attached) to classify snow/ice crystals.

Background Information:

List any safety concerns/cautions: appropriate cold weather clothing, slope of site.

Materials needed: crystal card, flat surface to scrape and collect sample (i.e. playing card).

Procedures/protocol:
1. The metric tape measure will be in place with zero (0) at ground level. Anchor body of tape measure on top of snow (zero at ground, increasing value with increase in height).
2. Review the finger test and knife test information that will show where distinctive layers in the stratigraphic profile are located
3. Use flat surface to gently collect snow sample from each distinctive snow layer
4. Compare crystal size and shape with the crystal card (provided), which contains images of the types of grain shapes. If this card is not available then use your descriptive skills to best describe what you observe.
5. Record crystal size and shape
6. Continue procedure down to ground surface

Data Table: (see following data table).

Snow Crystal Classification Data Table:

Depth (cm)	Approx. size	Shape

Sample Data Table (Lake Placid):

Depth	Approx. Size	Shape
35 cm	1 mm	2 dimensional/angular
30 cm	1 mm	2 D/ layered
25 cm	1 mm	More rounded/chunky
20 cm	1 mm	Angular/ 6 sided T-G within snow pack
15 cm	1 mm	Chunky/more rounded
10 cm	1 mm	Chunky/ rounded
5 cm	1 mm	Less chunky/plates
1 cm	1 mm	More chunky

Conclusion(s): Identify crystal size and shape from bottom to top - soft & hard layers, potential sliding surfaces, cursory: density and water content, weaknesses, strengths and bonding.

Density/% of water content

Research Area: Ice/Snow/Winter Ecology: Snow

Purpose of this "lesson": To identify density and percent of water content of snow from selected locations in the snow pack.

Brief Description: Collect sample of snow using thin walled Aluminum cylinder. The samples should be taken from locations identified in previous tests- to determine density and percent of water.

Background Information:

List any safety concerns/cautions: appropriate cold weather clothing, slope of site

Materials needed: Cylinder with measured diameter and length so that the volume is known. Balance or scale that will enable the weight of the cylinder with and without snow to be measured, flat thin metal plate that can be used to "shave" the ends of the metal density cylinder.

Procedures/protocol:
1. The metric tape measure or meter stick should be in place with: zero (0) at ground level. Anchor body of tape measure on top of snow (zero at ground, increasing value with increase in height).
2. Weigh the metal snow collection cylinders and make sure that each is numbered so that each number refers to a specific weighed cylinder.
3. Select location to sample using data collected from finger test and knife test. The idea is to select locations in the snow pack that relates to all the features that have been identified. You must characterize the snow pack and density and the respective snow water equivalent are important descriptors.
4. Push the cylinder into the snow face using the cylinder edges as push points. . The greatest error source is an incomplete fill of the cylinder. The best way to accomplish the "fill" is to push the cylinder in beyond the face surface and then cut a channel that will enable a metal shave plate to be used to dress off the back and front faces of the cylinder.
5. Weigh the cylinder (record number) with snow inside and then subtract the cylinder weight from the total weight to determine the weight of the snow in the predetermined cylinder volume.
6. Compute the density of the snow in the cylinder which is simply density =weight/volume. Then record the density. The water equivalent is simply the density multiplied by 100.
7. Continue procedure at selected layers down to ground surface.

Data Table: (see following data table).

Snow Pit Investigation Density/Water content Data Table:

Depth (cm)	Density (g/cc)	Water content (%)

Sample Data Table (Lake Placid):

Depth (cm)	Density (g/cc)*	Water content (%)**
10 cm	0.28	28%
30 cm	0.29	29%
50 cm	0.34	34%
70 cm	0.38	38%
90 cm	0.21	21%

Conclusion(s): Determine snow density and percent water content from bottom to top in the snow profile.

Color Atomizer Stratigraphy- (Optional)

Research Area: Ice/Snow/Winter Ecology: Snow

Purpose of this "lesson": To identify variations in stratigraphy and density and determine cause for variations.

Brief Description: Lightly spray colored water on vertical snow surface to observe snow pack.

Background Information:

List any safety concerns/cautions: appropriate cold weather clothing, slope of site.

Materials needed: spray bottle with red food coloring or other red colored liquid, broad fine paint brush, magnifying glass, camera.

Procedures/protocol:
1. Brush off vertical surface of snow to produce uniform surface.
2. Lightly spray vertical surface with red colored liquid. Lightly spray to enhance contrast and crystal structure.
3. Observe and differentiate hard/ice layers verses soft/unconsolidated layers. Relate these results to the finger and knife tests and the crystal studies.

Data Table: N/A

Sample data table (Lake Placid): N/A

Conclusion(s): Determine variations in snow color in order to relate to the snowpack structure.

Macro Invertebrates

Research Area: Ice/Snow/Winter Ecology: Snow

Purpose of this "lesson": To identify macroinvertebrates living on and in the snow.

Brief Description: Examine the surface and snow face for the presence of insect, arthropods and other invertebrates.

Background Information: Winter Ecology by Halfpenny and Ozanne.

List any safety concerns/cautions: appropriate cold weather clothing.

Materials needed: Hand lenses (10x or greater), Brock magniscopes ($\leq$400X), devices that will provide largest magnifications.

Procedures/protocol: Examine the surrounding area for evidence of macro-invertebrates record type and number present.

Organisms appear as "pepper" spilled on the snow (springtails), small spiders, mites that are *moving*. Note presence of liquid water, stem flow and other debris on snow surface. After several minutes of focused staring, it will appear surface of snow is dynamic and alive-never staying the same. Macroinvertebrate activity slows with decrease in temperature and is optimum at just above freezing, without being subject to extreme UV.

Data Table: N/A
Follow GLOBE macro-invertebrate protocols (normally applied only to water and aquatic habitats).

Sample data table (Lake Placid): N/A

Conclusion(s): Were there macro-invertebrates? What types and numbers? Is biodiversity of the site high or low? How does macro-invertebrate frequency relate to pH, hydrology protocols, air temperature, aspect, amount of liquid water present, etc?